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ABSTRACT

In response to the urgent national need to revitalize mathematics and science education, the National Research Council (NRC) has undertaken an examination of mathematics education from kindergarten through graduate study. This is a summary of a report outlining the seriousness of the situation and emphasizing how critical mathematics is for science, technology, and the economy. Sections included are: (1) "Opportunity" (stressing the importance of mathematics education); (2) "Change" (discussing an approach to reform and counterproductive influences); (3) "Transitions" (describing seven transitions that will dominate the process of change); and (4) "Action" (presenting national goals, national strategy, and actions for everyone). (YP)

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EVERYBODY COUNTS

A Report to the Nation on the Future of Mathematics Education

SUMMARY

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EVERYBODY COUNTS

A Report to the Nation on the Future of Mathematics Education

SUMMARY

Mathematical Sciences Education Board

Board on Mathematical Sciences

Committee on the Mathematical Sciences in the Year 2000

National Research Council

NATIONAL ACADEMY PRESS
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1989

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committees responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the author according to procedures approved by a report review committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. The Research Council functions in accordance with general policies determined by the Academy under the authority given to it in 1863 by its congressional charter, which established the Academy as a private, nonprofit, self-governing membership corporation. The Research Council is the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. Dr. Frank Press and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.

The Mathematical Sciences Education Board was established in 1985 to provide a continuing national overview and assessment capability for mathematics education and is concerned with excellence in mathematical sciences education for all students at all levels. The board reports directly to the Governing Board of the National Research Council.

The National Research Council created the Board on Mathematical Sciences in 1984. The objectives of the board are to maintain awareness and active concern for the health of the mathematical sciences and to serve as the focal point in the Research Council for issues connected with research in the mathematical sciences. Designed to conduct studies for federal agencies and to maintain liaison with the mathematical sciences communities, the board is part of the Commission on Physical Sciences, Mathematics, and Resources.

The Committee on the Mathematical Sciences in the Year 2000, which was appointed at the beginning of 1988, is a three-year joint project of the Mathematical Sciences Education Board and the Board on Mathematical Sciences. Its purpose is to provide a national agenda for revitalizing mathematical sciences education in U.S. colleges and universities.

Publication and dissemination of this book were supported by grants from Exxon Education Foundation, National Aeronautics and Space Administration, National Institutes of Health, National Research Council, National Science Foundation (Directorates for Biological and Behavioral and Social Sciences; Computer and Information Science and Engineering; Engineering; Geosciences; Mathematical and Physical Sciences; and Science and Engineering Education), Shell Oil Company Foundation, The Teagle Foundation, U.S. Department of Defense (Air Force Office of Scientific Research; Army Research Office; National Security Agency; and Office of Naval Research), and U.S. Department of Energy. The observations made herein do not necessarily reflect the views of the grantors.

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The complete volume of *Everybody Counts—A Report to the Nation on the Future of Mathematics Education* may be purchased from the National Academy Press, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

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FOREWORD

In response to the urgent national need to revitalize mathematics and science education, the National Research Council (NRC) has undertaken an examination of U.S. mathematics education from kindergarten through graduate study. Major studies being conducted for the NRC by the Mathematical Sciences Education Board, the Board on Mathematical Sciences, and their joint activity, the Committee on the Mathematical Sciences in the Year 2000 have the goals of identifying weaknesses in the present system as well as strengths to build on for the future.

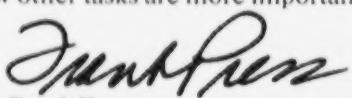
Everybody Counts is a public preface to the work of these three NRC units and other national organizations with which the NRC is cooperating in the revitalization of mathematics education. It outlines in stark terms the seriousness of the situation facing our country, emphasizing how crucial it is for science, technology, and the economy of the nation that *all* students receive high-quality education in mathematics. Yet, it goes well beyond this.

Numerous reports have appeared in recent years analyzing the problems of American education. *Everybody Counts* could easily be just one more report, pointing to problems and recommending that somebody, somewhere, should do something. Several features distinguish this report from others:

- it examines mathematics education as all one system, from kindergarten through graduate school;
- it treats all the major components of the system, from curricula, teaching, and assessment to human resources and national needs;
- it does not merely identify problems, but also charts a general course for the future, outlining a national strategy for pursuing that course;
- it is not the final report of a commission, but the beginning of a process through which teachers, state and local authorities, and the varied constituencies of mathematics education can draw together in a sustained revitalization effort.

This report reflects the thinking of 70 leading Americans, among them classroom teachers; college and university faculty and administrators; research mathematicians and statisticians; scientists and engineers; mathematics supervisors; principals; school superintendents; chief state school officers; school board members; members of state and local governments; and leaders of parent groups, business, and industry.

It also signals to the nation that—acting through the National Research Council—the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine are prepared to participate actively in the long-term work of rebuilding mathematics education in the United States. Few other tasks are more important to our children and to our nation.



Frank Press
President, National Academy of Sciences
Chairman, National Research Council

PREFACE

As science and technology have come to influence all aspects of life, from health and environment to financial affairs and national defense, so mathematics has come to be of vital importance to the educational agenda of our nation. Mathematics is the foundation of science and technology. Increasingly, it plays a major role in determining the strength of the nation's work force. Yet, evidence all around us shows that American students are not fulfilling their potential in mathematics education.

Three of every four Americans stop studying mathematics before completing career or job prerequisites. Most students leave school without sufficient preparation in mathematics to cope with either on-the-job demands for problem-solving or college expectations for mathematical literacy. Industry, universities, and the armed forces are thus burdened by extensive and costly demands for remedial education. Our country cannot afford continuing generations of students who by lack of mathematical power are limited to second-class status in the society in which they live. It cannot afford to weaken its preeminent position in science and technology.

The three units that we chair at the National Research Council have committed themselves to remedying this situation. As a first step, we commissioned Lynn Arthur Steen, professor of mathematics at St. Olaf College, to write a synthesis of the thinking developed through three years of analysis by the Mathematical Sciences Education Board, two years of involvement by the Board on Mathematical Sciences (which deals with research), and the first year of work by their joint activity, the Committee on the Mathematical Sciences in the Year 2000, which is concerned with college and university mathematics.

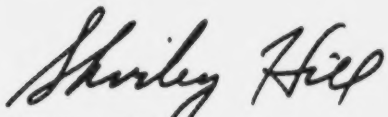
Everybody Counts describes various forces that impinge on mathematics and on education—computers, research, demography, competitiveness—and explains how each is a major force for change, and yet interactions among these forces produce a system that is peculiarly resistant to change. The problems are complex. While the facts are indisputable, there is not complete unanimity on interpretations, priorities, or proposed solutions, even within the scientific community. Nevertheless, change must come. When one compares the potential return on investment in education with the consequences of inaction, it becomes clear that we as a nation have no choice: we must improve the ways in which our children learn mathematics.

Not merely a cry for reform, *Everybody Counts* points to specific transitions that our nation's schools and colleges must make in their mathematics programs over the next two decades if they are to meet the needs of students and the country as well as the accelerating momentum of a grass-roots reform effort already well under way. It argues for the development of a national support structure to undergird that effort and describes major pieces of such a structure to be put in place over the next year. Its intent is to seek a broad consensus on a national strategy for getting the job done. Throughout, the report reflects our prime concern that, whatever any of us do as individuals or through

organizations to improve education, we see our role as supporting the efforts of the central person who can bring about meaningful and lasting change: the teacher.

We take this opportunity to express our gratitude to Lynn Steen for applying his considerable writing talents to the task of creating *Everybody Counts*. He has described in eloquent language the complex issues of mathematics education with which we shall be grappling for years to come.

The Summary of *Everybody Counts* was prepared by Kenneth M. Hoffman. It focuses primarily on the "Change" and "Action" chapters, which describe in condensed form the challenges facing mathematics education in the United States, the transitions that are under way in schools and colleges in response to those challenges, and the outline of a national action plan for accomplishing the transitions on a widespread basis. No pretense is made of capturing the essential content of *Everybody Counts*, which is contained in the reasoned arguments of five chapters: Opportunity, Human Resources, Mathematics, Curriculum, and Teaching, condensed here into a few pages. No technical background is necessary for appreciating the full report and we recommend it strongly to the interested reader.



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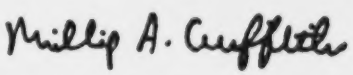

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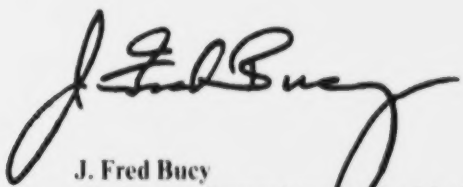

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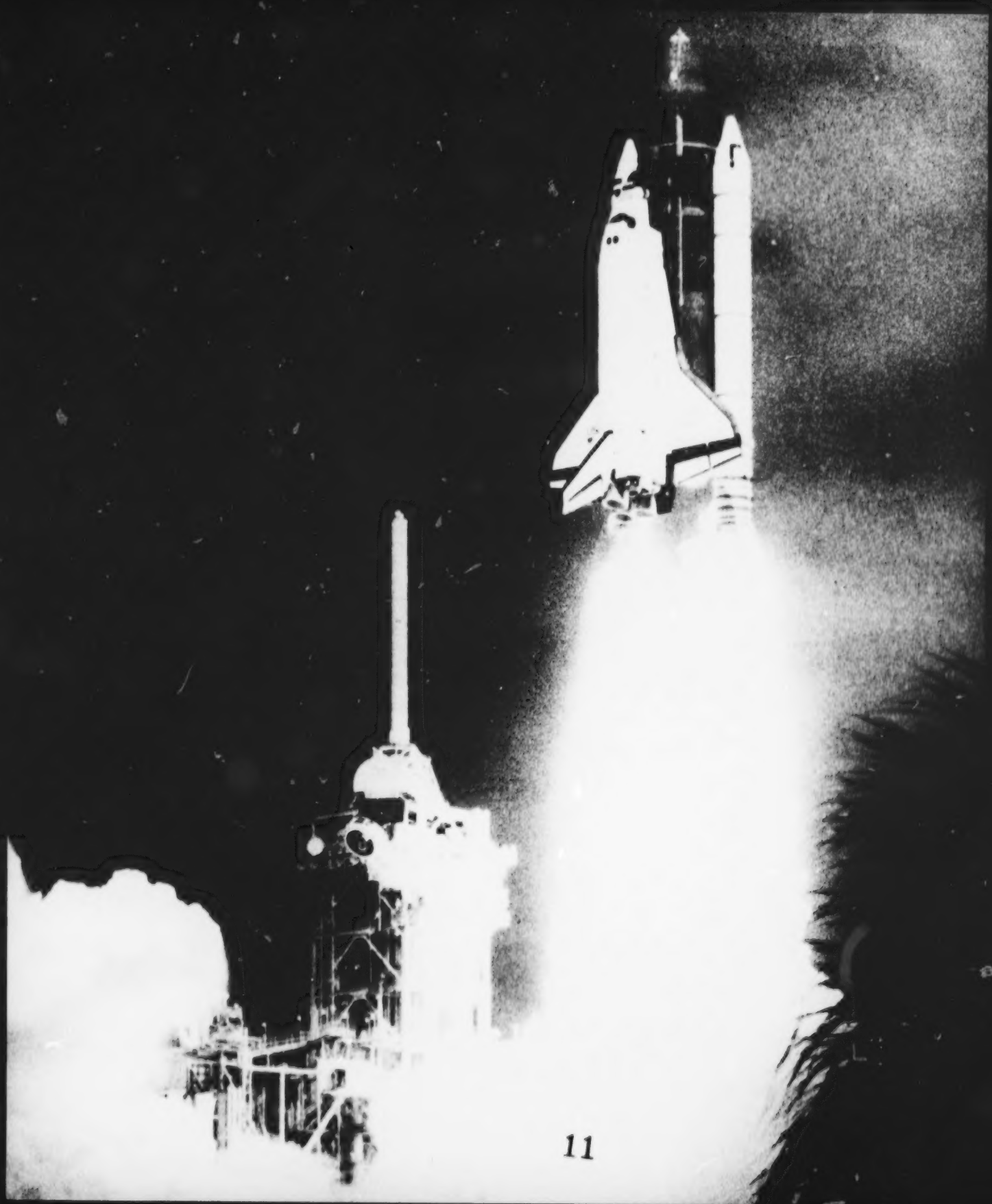
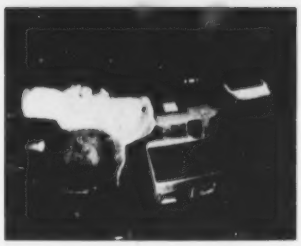




OPPORTUNITY

. . . tapping the power of mathematics

As the 1980's began, an inattentive nation began stirring in response to alarming problems in its educational system. Since then, dozens of reports have analyzed virtually every aspect of U.S. education. Some call for changes in curricula, others for changes in the structure of schools; some cite deficiencies in the ways that teachers are educated, while others examine signs of decay in the social and economic structures of society. All agree that the present educational system must change.

The concern here is with mathematics, which is—apart from English—the most widely studied subject in our nation's schools and colleges. Mathematics education is an immense enterprise involving 35 million students and over a million and a half teachers, accounting for more than 10 percent of the nation's educational expenditures—about $25 billion annually. It is an enterprise rooted in antiquity, with some of today's curricula matching very closely educational patterns of 500 years ago. **Yet, paralleling the larger system of which it is a part, mathematics education has entered a period of significant change, certain to last well into the next century.**

National Needs

Not only in mathematics but also in every other school subject, educators are faced with significant demographic changes and rising expectations for preparing the kind of work force the country will need in the future. Information-age technology will continue to grow in importance. Pressed by rising international competition, American industry will demand improved quality and increased productivity. The world of work in the twenty-first century will be less manual but more mental; less mechanical but more electronic; less routine but more verbal; and less static but more varied.

"Changing demographics have raised the stakes for all Americans. Never before have we been forced to provide true equality in opportunity to learn. The challenge we face today is to achieve what we believe."

The quotations displayed throughout this book are excerpted from the text of *Everybody Counts.*

Communication has created a world economy in which working smarter is more important than just working harder. Jobs that contribute to this world economy require workers who are mentally fit—workers who are prepared to absorb new ideas, to adapt to change, to cope with ambiguity, to perceive patterns, and to solve unconventional problems. It is *these* needs, not just the need for calculation (which is now done mostly by machines), that make mathematics a prerequisite to so many jobs. **More than ever before, Americans need to think for a living; more than ever before, they need to think mathematically.**

Schools

Historically, schools in the United States were designed with a dual mission: to teach all students the basic skills required for a lifetime of work in an industrial and agricultural economy and to educate thoroughly a small elite who would go to college and then pursue professional careers. As the needs of society have changed, the balance of these two goals has shifted. Although schools have adapted somewhat, today's schools continue to labor under the legacy of a structure designed for the industrial age misapplied to educate children for the information age.

The changing nature of work will make continuing education a lifelong reality for adults. Schools, therefore, will have to provide all students with a strong foundation for continuous learning; colleges and universities will have to educate both young adults and older workers; and industry will have to focus its continuing education on areas that extend, rather than repeat, what schools provide. **Education in the future must build continually, from childhood to retirement, on a versatile and unbroken foundation provided by school education.**

Literacy and Numeracy

Literacy and numeracy—that is, proficiency in language and in mathematics—are the primary sources of strength and versatility in school education. Schools and colleges will have to meet goals now widely held to be unattainable:

- The level of literacy formerly associated with the few who entered college must become a goal for all.
- The degree of facility with mathematics formerly required only of those preparing for scientific careers is now an essential ingredient in the foundation for working careers in the information age.

Mathematical and scientific literacy form the basis of technological expertise in the workplace. In tomorrow's world, the best opportunities for jobs and advancement will go to those prepared to cope confidently and competently with mathematical, scientific, and technological issues. **As the foundation of science and technology, mathematics provides the key to opportunity.**

Opportunity for the Nation

The focus in what follows is on a bold but realistic approach to reforming mathematics education as schools and colleges work toward the demanding objectives now before them. Means must be found for significantly improving student achievement while simultaneously making changes in mathematics education in response to the demands of an increasingly mathematical society. The changes proposed here are:

- rooted in traditional values, yet reflect the greatly increased applicability of mathematics to problems faced almost daily by scientist, engineer, worker, and citizen;
- guided by national goals, but respect state and local autonomy;
- built on the educational reform effort already under way;
- to be carried out locally by the only people who can bring about meaningful and lasting reform—the teachers.

Among the several insights and messages that this report is intended to convey is this uniquely important one: because of emerging general agreement within the mathematics, mathematics education, and related professional communities on the goals for mathematics education and the means for achieving them, the stage is set for the nation to push ahead boldly in this area of education. **In the next decade, the United States has a historic opportunity to revitalize mathematics education.**

CHANGE

. . . mobilizing for reform

Mathematics education in the United States is facing major challenges on nearly every front:

- Far too many students, including a disproportionate number from minority groups, leave school without having acquired the mathematical power necessary for productive lives.
- The shortage of qualified mathematics teachers in this country is serious, more serious than in any other area of education, and affects all levels from elementary school to graduate school.
- At a time when the percentage of minority students is increasing, the shortage of new minority teachers of mathematics is particularly acute.
- On average, U.S. students do not master mathematical fundamentals at a level sufficient to sustain our present technologically based society.
- When compared with students of other nations, U.S. students lag far behind in level of mathematical accomplishment; the resulting educational deficit reduces our ability to compete in international areas.
- Public attitudes, which are reflected and magnified by the media, encourage low expectations in mathematics. Only in mathematics is poor school performance socially acceptable.

"As technology has 'mathematicized' the workplace and as mathematics has permeated society, a complacent America has tolerated underachievement as the norm for mathematics education. We have inherited a mathematics curriculum conforming to the past, blind to the future, and bound by a tradition of minimum expectations."

- Curricula and instruction in our schools and colleges are years behind the times; they reflect neither the increased demand for higher-order thinking skills, nor the greatly expanded uses of the mathematical sciences, nor what we now know about the best ways for students to learn mathematics.
- Calculators and computers have had virtually no impact on mathematics instruction in spite of their great potential to enrich, enlighten, and expand students' learning of mathematics.
- Commonly employed methods of evaluation—especially standardized, paper-and-pencil, multiple-choice tests of "basic skills"—are themselves obstacles to the teaching of higher-order thinking skills as well as to the use of calculators and computers.
- Undergraduate mathematics is intellectually stagnant, overgrown with stale courses that fail to stimulate the mathematical interests of today's students.

Counterproductive Beliefs

It is mistakenly thought by many otherwise well-informed adults that the mathematics they learned in school is adequate for their children. But mathematics has changed. It is significantly more diverse than it was several decades ago when most of today's adults went to school. The mathematics commonly used today goes far beyond arithmetic and elementary geometry. Members of the armed forces as well as workers in manufacturing and the burgeoning service sector are called upon regularly to operate complex machines and to interpret graphs, data, and probabilities.

Parental and legislative pressures in the past few years, driven largely by frustration over declining test scores, have led to some rash actions:

- Increased numbers of required courses—where there is no agreement on what the added courses should contain or where capable teachers are to be found to teach them.
- Increased reliance on standardized tests—where there is very little understanding of what the tests contain or what they are capable of testing.
- Increased use of test scores, especially for teacher and school accountability—where there is little recognition that the tests reflect only a small part of curricular objectives.

Too often, the results of such actions are unreliable tests, watered-down curricula, and diminished morale. The nation is in the grip of a testing mystique that has led to widespread misuse of standardized tests. **Public pressures for "back-to-basics" stem from a very limited understanding of the challenges we face. Carried to the extreme, these pressures could rob our children of the opportunity to learn what they will need to know of mathematics in their adult lives.**

"As mathematics is more than calculation, so education in mathematics must be more than mastery of arithmetic."

Public Understanding

Appropriate response to the challenges of mathematics education will require a systematic effort to develop in the public a deeper understanding of the changes and the improvements needed. This will be a formidable task.

Often, public discussion about mathematics education masks a hidden agenda of values that have traditionally been carried forward by the school study of mathematics. Since the demise of Latin as a required school subject, it is to mathematics that many look as a vehicle to instill such qualities as precision, discipline, neatness, and accuracy. Mathematical truth—in popular caricature—is certain, absolute, unchanging, eternal. Mathematics appears to many to be a safe harbor of calm in a turbulent sea of social and educational change.

In spite of the fact that it is constantly expanding and changing, mathematics more than any other science has been taught as an ancient discipline. **A nation that persists in this antiquated view of mathematics is destined to fall behind scientifically and economically. Parents who persist in this view are denying their children the opportunity to develop and prosper in the information age.**

"As children become socialized by school and society, they begin to view mathematics as a rigid system of externally dictated rules governed by standards of accuracy, speed, and memory. Their view of mathematics shifts gradually from enthusiasm to apprehension, from confidence to fear."

The American Way

The development of more effective strategies for revitalizing mathematics education must be based in part on an understanding of why it is so difficult to bring about change in education in the United States. The truth we shrink from confronting is that most previous reform efforts have failed. A skeptical public will rightly ask why any new effort is more likely to succeed. Part of the difficulty we face in mathematics education is a natural reflection of our constitutional dilemma: how to reconcile local authority with national need.

In many countries, all children in the same grade study essentially the same material in almost the same way. Such practice, common around the world, reveals a strong tradition of a "top-down" approach in education.

The process of curricular reform prevalent in America might be described as a weak type of grass-roots approach. With little or no outside help, teacher teams at the local level work over the summer in efforts to keep mathematics curricula up to date.

In static times, in periods of unchanging demands, perhaps our grass-roots efforts could suffice to keep curricula current. In today's climate, in which technology and research are causing unprecedented changes in the central methods and applications of mathematics, present U.S. practice is totally inadequate. **International comparisons of student performance in mathematics show that U.S. students lag far behind their counterparts in other industrialized countries. The "top-down" systems have beaten us hands down.**

"Why Not Just Imitate Japan?

International studies of mathematics and science education show that, when compared with students in other countries, U.S. students do very poorly while Japanese students do very well. One natural response, therefore, is to think that we could improve our educational system by imitating Japan.

These same studies, however, document that the social context of education has a greater influence on student performance than does actual classroom practice. Parental attitudes, student expectations, and teacher self-respect are among the most significant factors in quality education and they depend uniquely on culture.

Imitating others is no solution. The United States must find a strategy that builds on the traditions of this country, one whose strength lies in this nation's unique tradition of local initiative and decentralized authority."

Lessons from the Past

Because of vast differences in both tradition and constitution, a "top-down" approach will not work in the United States. Experience has much to teach us on that score.

Few traces remain of the expensive, major curriculum development projects so prominent in the 1960's and 1970's. These projects tried to develop, on a national scale, complete curricula (including instructional materials) that could be adopted as a whole by school districts. But the theorists and planners who developed these curricula were naive about the process of change; big curricular projects failed to take root in American schools because they were transplanted fully grown into an environment better suited to locally grown methods.

Where teachers were not directly involved in development, where their identification with the product was not ensured, where they considered district acceptance of new curricula as a "top-down" imposition, the revised programs did not last. **Where parents could not (or did not) understand the need for change or the reasons new curricular emphases were chosen, resentment and anger resulted and a conviction set in that if "the old math" was good enough for them, it was good enough for their children.**

A New Approach

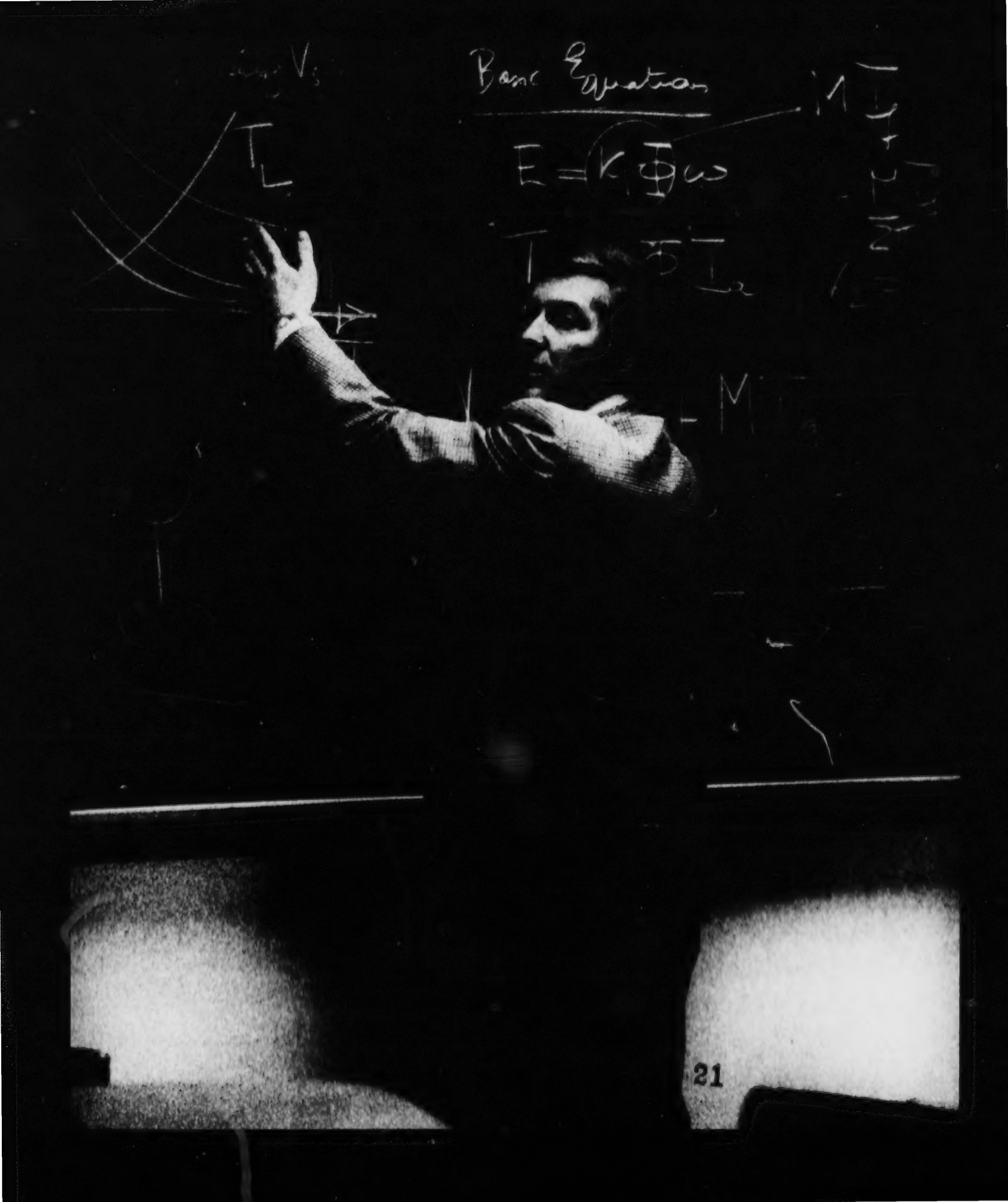
As our country enters a new period of change in mathematics education, we can benefit from several lessons drawn from these previous attempts:

- Free-standing, full-service curriculum development projects adopted intact by school districts do not work.
- A superficial, district-by-district approach to curricular overhaul is potentially disastrous, given the demanding nature of what schools face in mathematics education today.
- Any successful effort to improve mathematics curricula and instruction in the schools will require an extensive public information campaign that reaches all the varied constituencies of mathematics education.

Effective change requires a great deal of the public:

- conviction of the need for change;
- consensus on the importance of high-quality mathematics education for everyone;
- skepticism about "quick fixes" and simplistic solutions;
- awareness of the general nature of the changes needed;
- support for investment of the necessary resources;
- recognition of the need for continuing leadership at the national level.

The time is ripe for a new approach to curricular reform in the United States—one that establishes appropriate national expectations based upon broad public support by all of the constituencies concerned.


Basic Equation
21

TRANSITIONS

. . . bridges to the 21st century

In order to meet the challenges of our time, mathematics education is beginning already to negotiate several difficult transitions that will dominate the process of change during the remainder of this century.

Transition 1: *The focus of school mathematics is shifting from a dualistic mission—minimal mathematics for the majority, advanced mathematics for a few—to a singular focus on a significant common core of mathematics for all students.*

The needs of industry for a mathematically and technically literate work force compel schools to provide more mathematical education to more students than ever before. Accomplishing this will pose significant challenges to:

- develop a core of mathematics appropriate for all students throughout each year of school;
- educate well a significantly larger proportion of the population;
- stimulate able students with the excitement and challenge of mathematics;
- differentiate instruction by approach and speed, not by curricular goals;
- select topics and approaches of broad interest and effectiveness.

Transition 2: *The teaching of mathematics is shifting from an authoritarian model based on "transmission of knowledge" to a student-centered practice featuring "stimulation of learning."*

In both schools and colleges, classrooms of passive students who are expected to sit and absorb rules that appear as arbitrary dicta are

"Everyone depends on the success of mathematics education; everyone is hurt when it fails. Mathematics must become a pump rather than a filter in the pipeline of American education."

gradually giving way to learning environments that:

- encourage students to explore;
- help students to verbalize their mathematical ideas;
- show students that many mathematical questions have more than one right answer;
- provide evidence that mathematics is alive and exciting;
- teach students through experience the importance of careful reasoning and disciplined understanding;
- build confidence in *all* students that they can learn mathematics.

Transition 3: *Public attitudes about mathematics are shifting from indifference and hostility to recognition of the important role that mathematics plays in today's society.*

Although the burden of unfavorable school experiences continues to color public opinion about mathematics, contemporary events are sending different messages which are gradually being heard:

- in other nations where more is expected, more mathematics is learned;
- as the roles of science and technology expand, so does the importance of mathematics;
- for an informed citizenry, mathematical literacy is as important as verbal literacy.

As attitudes about the importance of mathematics improve, so will expectations for mathematics education.

Transition 4: *The teaching of mathematics is shifting from preoccupation with inculcating routine skills to developing broad-based mathematical power.*

Broad mathematical power requires that students be able to discern relationships, reason logically, and use a range of mathematical methods to solve a wide variety of nonroutine problems. The repertoire of skills which now undergird mathematical power includes not only some traditional paper-and-pencil skills, but also many broader and more powerful capabilities. Today's students must be able to:

- perform mental calculations and estimates with proficiency;
- decide when an exact answer is needed and when an estimate will serve the purpose;
- know which mathematical operations are appropriate in particular contexts;
- use a calculator correctly, confidently, and appropriately;
- estimate orders of magnitude to confirm mental or calculator results;
- use tables, graphs, spreadsheets, and statistical techniques to organize, interpret, and present numerical information;
- judge the validity of mathematical and technical information presented by others;
- use computer software for mathematical tasks;
- formulate specific questions from vaguely defined problems;
- select effective problem-solving strategies.

"Evidence from many sources shows that the least effective mode for mathematics learning is the one that prevails in most of America's classrooms: lecturing and listening."

Transition 5: *The teaching of mathematics is shifting from emphasis on preparation for future courses to greater emphasis on topics that are relevant to students' present and future needs.*

Most mathematics should be presented in the context of its uses, with appreciation of mathematics as a deductive logical system built up slowly through the rising levels of education. Examples of areas deserving greater emphasis are:

- probability, which facilitates reasoning about uncertainty and assessment of risk;
- exploratory data analysis and statistics, which facilitate reasoning about data;
- model-building, which facilitates systematic structured understanding of complex situations;
- operations research, which facilitates planning complex tasks and achieving performance objectives;
- discrete mathematics, which facilitates understanding of most applications of computers.

These new topics imply that observation and experimentation will be important in future mathematics programs and that school mathematics will draw closer to other school subjects, especially to science.

Transition 6: *The teaching of mathematics is shifting from primary emphasis on paper-and-pencil calculations to full use of calculators and computers.*

Mathematics teachers at all levels—from elementary school to university—are adapting their teaching methods to include both new approaches to instruction and new subject matter appropriate to future-oriented curricula. Calculators and computers make new modes of instruction feasible at the same time that they inject into the learning environment the special sense of wonder which goes with the healthy development of mathematical power.

Calculators and computers should be used in ways that anticipate continuing rapid change due to technological developments. Technology should be used not because it is seductive, but because it can improve mathematical learning by extending each student's mathematical power. Calculators and computers are not substitutes for hard work or precise thinking, but challenging tools to be used for productive ends.

Transition 7: *The public perception of mathematics is shifting from that of a fixed body of arbitrary rules to a vigorous active science of patterns.*

Mathematics is a living subject that seeks to understand patterns which permeate both the world around us and the mind within us. Although the language of mathematics is based on rules that must be learned, it is important that students move beyond rules to be able to express things in the language of mathematics. This transformation suggests change in both curricular content and instructional style. It involves renewed effort to focus on:

- searching for solutions, not just memorizing procedures;
- exploring patterns, not just learning formulas;
- formulating conjectures, not just doing exercises.

As teaching begins to reflect these emphases, students will have opportunities to study mathematics as an exploratory, dynamic, evolving discipline rather than as a rigid, absolute, closed body of laws to be memorized. They will be encouraged to see mathematics as a science, not as a canon, and to recognize that mathematics is really about patterns and relationships and not merely about numbers.

"As a practical matter, mathematics is a science of pattern and order. Its domain is not molecules or cells, but numbers, chance, form, algorithms, and change."

ACTION

. . . a new national strategy

Over the next two decades, all of the major components of mathematics education—curricula, teaching, teacher education, testing, textbooks, and software—must change significantly and in some reasonably coordinated manner. National leadership is needed to coordinate efforts by the primary agents for change and to garner support for them by government, business, industry, and the public.

National Goals

Our national goal must be to make U.S. mathematics education the best in the world. Nothing less will be adequate to fulfill American aspirations. To achieve this goal will require significant actions in response to a three-tiered challenge to:

- make mathematics education effective for all Americans;
- improve significantly students' mathematical achievement;
- put in place new curricula appropriate to the mathematical needs of the twenty-first century.

Actions taken to achieve these broad goals must be based upon an understanding of the total American system of mathematics education, especially understanding of the nature of the changes under way. Unless action is based upon a systematic overview of all of the pertinent issues, it will have very little chance of achieving national impact.

"All students should study mathematics every year they are in school. Secondary school mathematics should provide for all students a core of mainstream mathematics in which different student groups are distinguished not by curricular goals, but only by speed, depth, and approach."

National Strategy

New plans for the renewal of school mathematics must be founded on what we have learned about making changes in the extremely decentralized U.S. system in which local and state agencies control education. Two special strengths of American mathematics education should underpin any movement for renewal:

- The creative efforts of many individuals, schools, and projects around the country, which have begun to move mathematics education through the transitions just described here.
- The unique form of coordinated national leadership, which has evolved within the communities of mathematicians and mathematics educators.

Together, these resources provide an "augmented grass-roots" model of curricular development, coupling national leadership with the flexibility and initiative of the decentralized U.S. tradition.

A national strategy for revitalization which is well suited to the unique strengths and weaknesses of U.S. mathematics must have several major components:

National goals and local implementation. The key to success is voluntary acceptance by school districts of common goals that provide a framework to guide local choices and the construction of detailed programs.

- *National Standards.* School mathematics programs across the nation need to share a common philosophy and framework—a universal set of interrelated concepts and methods held together by a simple workable philosophy, yet flexible enough to allow for local and regional variations. In a highly mobile society, the basic framework should be transportable and adaptable.
- *Local Implementation.* Changes in mathematics curricula must be proposed and undertaken freely by those who bear direct responsibility for curricula in the schools. A deep sense of identification with those changes must be developed within the entire school community. In particular, local teachers and parents need to be involved in adaptation and decision-making in a thorough and comprehensive way.

National discipline-based leadership, such as that now being supplied by the mathematics and mathematics education communities—working with leaders from the diverse constituencies of mathematics education—is needed to:

- lay out the consensual framework, including proposed national standards;
- coordinate an effort to build and sustain national consensus on goals and the approach to be used to achieve them;
- provide a continuing national overview and assessment capability for mathematics education.

State and local coalitions, collaboratives, and teacher support networks will be needed to provide similar leadership at these levels.

National, state, and local leadership—provided by the President, Congress, federal officials, governors, chief state school officers, mayors, legislators, school boards, school superintendents, principals, teachers, and college and university faculty and administration—will be of critical importance to the consensus-building effort and to local adoption of the national standards. National and state education-related organizations, parent groups, business, and industry can also play important leadership roles.

National support structures are needed to enable the primary participants—teachers, schools, state and local education authorities—to work successfully toward national goals in their continuous efforts to upgrade mathematics programs. Local, state, and federal resources should be used cooperatively to provide the variety of materials, teacher support, and increased public awareness necessary to enable teachers to adapt curricula and instructional practices within the nationwide consensual framework.

Teacher professionalism must be strengthened through a concerted national effort. This is an essential element of any effective strategy for reforming mathematics education in the United States. It is the teachers on whom the real burden of reform rests. The task we are setting before them is very demanding and will take many years. Teachers need to approach this task in a highly professional way and they need to be

given the sustained support and working environments that will make it possible for them to carry out their vital mission. Initiation of the National Board for Professional Teaching Standards is an important step toward enhancing teacher professionalism. Criteria for excellence in mathematics teaching being developed by the mathematics education community should provide part of the foundation for the standards developed by the board as it undertakes the certification of professional teachers.

Leadership in assessment is needed to align state and national testing programs with the goals of mathematics education and enable assessment to be a constructive force in the national revitalization effort. Test designers and test-makers are well aware of the general problems in this area. They need to join together with the leadership of mathematics education in support of a cooperative national board or other mechanism for promoting use of significantly improved types of assessment by localities, states, and national assessment organizations.

A national plan for college and university mathematics must be developed, one which is closely allied with the plan for school mathematics. This is needed not only because there must be consistency at the school-college interface, but also because college and university faculty influence heavily who become teachers, how they teach, and what they teach. Undergraduate mathematics is the bridge between research and the schools and holds the power of reform in mathematics education. The National Research Council (NRC) Committee on the Mathematical Sciences in the Year 2000 (Project MS 2000) is developing such a plan.

Significant movement to implement this seven-part national strategy is under way through the combined efforts of national organizations, including those concerned directly with mathematics and mathematics education, as well as foundations, national education organizations, parent groups, and agencies of government.

"Few teachers in today's schools have the authority or resources necessary to carry out this agenda. But as schools evolve from a model with teachers as hired hands to one in which teachers function as professional educators, schools should welcome the challenge to implement national standards for mathematics education."

Building Consensus

The *Curriculum and Evaluation Standards for School Mathematics*, developed by the National Council of Teachers of Mathematics (NCTM) and being released in March 1989, is the linchpin of the strategy. It focuses national attention on specific objectives for school mathematics in the 1990's. These standards from the teaching profession provide guides to what constitutes excellence in school mathematics programs designed to serve *all* students, from kindergarten through high school. Already reviewed extensively in draft form by mathematics teachers and the public, the standards have received widespread support in the mathematical and educational communities. They represent the very first effort to establish national goals for school mathematics. The nation has a unique opportunity to build consensus around these goals.

Generating Dialogue

The development and publication of the NCTM *Standards* are part of the national, discipline-based leadership referred to in the strategy. The NRC took two other steps: the establishment in 1985 of the Mathematical Sciences Education Board (MSEB), to provide continuing national oversight and coordination in mathematics education at all levels, and the formation in 1988 of the Committee on the Mathematical Sciences in the Year 2000, to recommend a revitalization plan for college and university mathematics. Both of these steps were taken at the request of the professional societies in mathematics and mathematics education in the United States.

The NCTM *Standards* report is one of a series of major reports appearing in 1989, to which *Everybody Counts* is a public preface. Others are MSEB's *Philosophy and Framework for School Mathematics* and *Strands of the Mathematics Curriculum*.

A related report comes from the American Association for the Advancement of Science's Project 2061. Called *Science for All Americans*, it sets forth a vision of what every young person should learn about mathematics, science, and technology.

These reports could join hundreds of other well-meant reports on the nation's bookshelves or they could make a difference. To bring their messages to the many "attentive publics" of mathematics education and help build consensus on their goals, the Mathematical Sciences Education Board plans to coordinate an intensive Year of National Dialogue that will accompany publication of these reports—a dialogue carried directly to teachers, administrators, policymakers, business, industry, government, and the general public. Professional organizations in the mathematical sciences are making plans for active involvement in this dialogue. Numbers of other national, state, and local organizations will participate.

"Implementation will require more than good will and community dialogue; it will need professional leadership of teachers operating in a transformed school environment. No one should underestimate the complexity of the challenge; effective reform will be truly difficult to accomplish."

Taking Action

Current efforts to forge national consensus will not in themselves transform what happens in schools or colleges. Change in the institutions of education must come about as the result of intensive debate within each institution. There is plenty of work for everyone:

STUDENTS

- Study mathematics every school year.
- Discover the mathematics that is around us all.
- Use mathematics in other classes and in daily life.
- Study a broad variety of mathematical subjects.

TEACHERS

- Talk with each other about mathematics.
- Examine current practice and debate new proposals.
- Engage students actively in the process of learning.

PARENTS

- Demand that schools meet the new NCTM *Curriculum and Evaluation Standards for School Mathematics*.
- Encourage children to continue studying mathematics.
- Support teachers who seek curricular improvements.
- Expect homework to be more than routine computation.

PRINCIPALS

- Provide opportunities for teachers to work together.
- Become educated on issues in mathematics education.
- Support innovation.
- Encourage paired teaching in elementary school.

SUPERINTENDENTS

- Stimulate public discussion of mathematics education.
- Provide resources for curricular innovation.
- Support a climate of change.

SCHOOL BOARDS

- Establish appropriate standards for mathematics.
- Align assessment with curricular goals.
- Support innovation and professional development.

COMMUNITY ORGANIZATIONS

- Enrich mathematical opportunities for all students.
- Support local efforts to improve mathematics education.
- Explain to the public the need for change.

STATE SCHOOL OFFICERS

- Promote adoption of NCTM's *Curriculum and Evaluation Standards for School Mathematics*.
- Encourage use of elementary mathematics specialists.
- Speak out publicly about mathematics education.
- Stress assessment of higher-order thinking.

COLLEGE AND UNIVERSITY FACULTY

- Make introductory courses attractive and effective.
- Restore integrity to the undergraduate program.
- Lecture less; try other teaching methods.
- Link scholarship to teaching.

COLLEGE AND UNIVERSITY ADMINISTRATORS

- Reward curricular innovation and good teaching.
- Recognize that mathematics classes need computer laboratories.
- Diminish reliance on underprepared, part-time faculty.
- Emphasize and improve teacher education.

BUSINESS AND INDUSTRY

- Encourage students to study mathematics and science.
- Do not steal good teachers by hiring them away.
- Support local efforts to secure funds for education.
- Support strong continuing education, not remediation.
- Provide internship opportunities for teachers.

STATE LEGISLATORS

- Work with school leaders to support effective programs.
- Recognize that mathematics education is an investment.
- Resist pressures for simplistic cures.

GOVERNORS

- Provide resources to encourage change.
- Demand new standards for mathematics education.
- Lead the public to make wise choices among priorities.
- Create enrichment programs for able students.

CONGRESS

- Stress education as an essential investment.
- Support mathematics education at all levels.
- Reward effective programs.

THE PRESIDENT

- Meet with state governors to affirm the national agenda.
- Focus public attention on mathematics education.
- Stress education as crucial to national security.

CONCLUSION

. . . it is time to act

This is just the beginning. Several decades of work lie ahead if we are to translate the ideas put forth here into classroom practice. During that time, continuous change in mathematics programs should be the norm in most of the nation's school districts. Strong national, state, and local leadership will be needed all along the way.

Efforts to bring about lasting change must proceed steadily for many years, on many levels simultaneously, with the broad involvement of all of the constituencies at each stage. First comes serious discussion; then, compromise and consensus; finally, action and change. At national, state, and local levels, significant efforts are under way to improve curricular standards, the teaching profession, and assessment practices. Major projects are being started to help the diverse efforts of business, industry, government, volunteer groups, and educational organizations to focus on common objectives. As there is no royal road to geometry, so there are no "quick fixes" for mathematics education.

Both for reasons of international competitiveness and scientific leadership, the United States must move quickly to improve the state of mathematics education. It takes a generation to complete the mathematical education of a single individual. The first high school graduates of the next century entered elementary school in 1988. No longer can we afford to sit idly by while our children move through school without receiving the mathematical preparation appropriate for the twenty-first century.

The challenges are clear. The choices are before us. It is time to act.

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